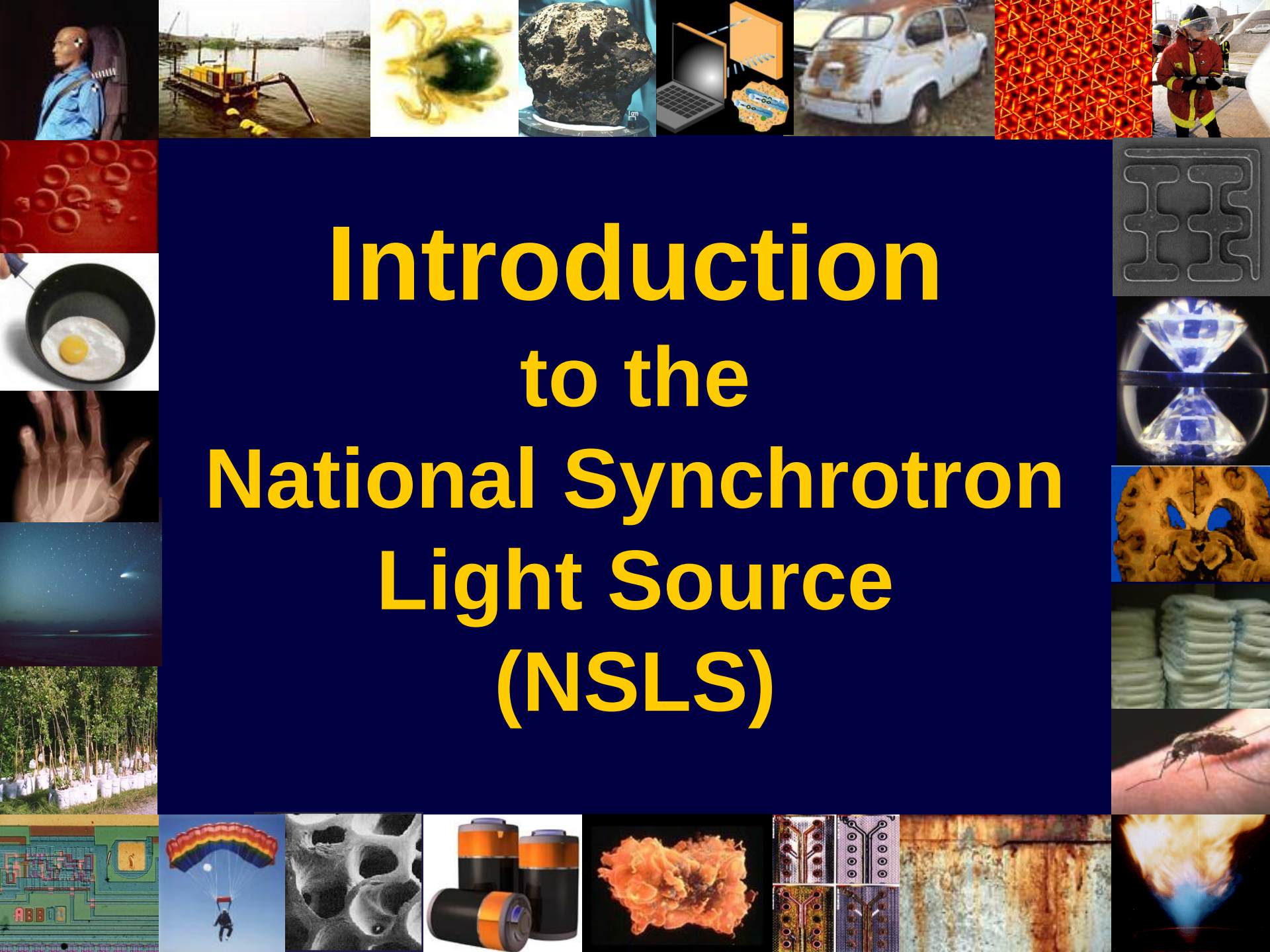


Introduction
to the
National Synchrotron Light Source (NSLS)

Outline

- The Facility
- The Users
- The Science
- The Future

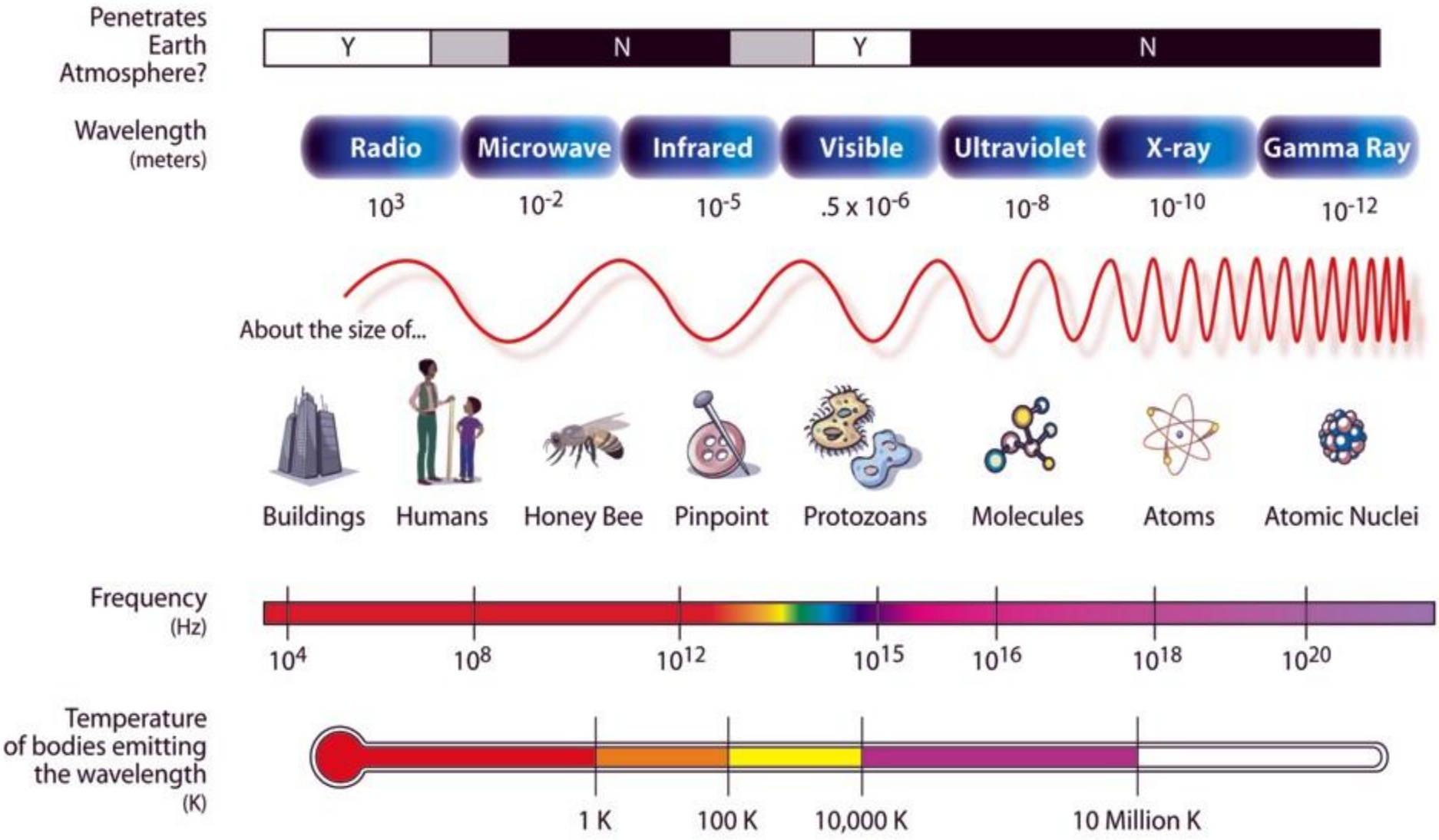
Brookhaven National Laboratory

What is a Synchrotron?

A synchrotron is a facility that produces tiny beams of very bright

X-RAYS | ULTRAVIOLET LIGHT | VISIBLE LIGHT | INFRARED LIGHT | MICROWAVES

THE ELECTROMAGNETIC SPECTRUM



First Synchrotrons

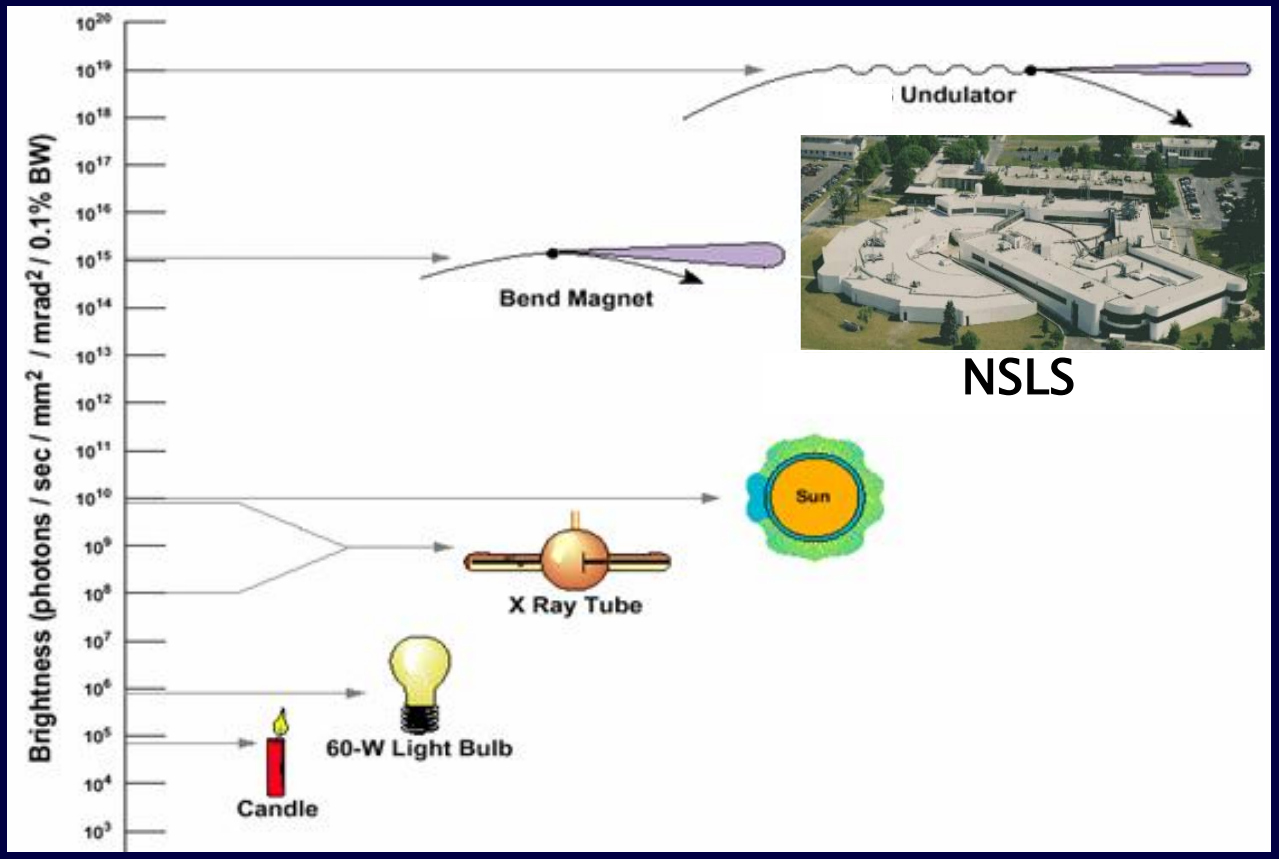
- First particle accelerators (cyclotrons) were used to “split the atom”.
- First synchrotron was built in 1947 by General Electric.
- Synchrotron radiation was given off by these accelerators and was seen to be a nuisance.
- In the 1960’s it was realized that this would be a useful source of radiation – a new light source.

Properties of Synchrotron Light

- **Broad band** – a wide energy range of photons is available
- **Polarized** – this minimizes background scattering, improves sensitivity and enables measurement of circular dichroism
- **Pulsed** – the electron bunches produce nanosecond light pulses, enabling process kinetics to be followed and ‘movies’ of reactions to be made.

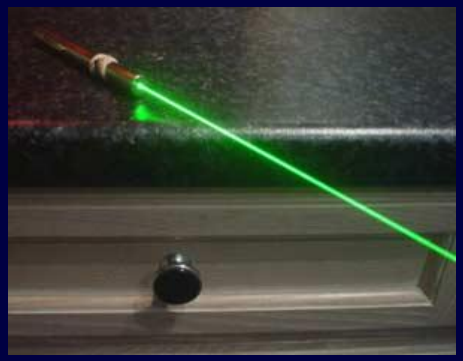
Properties of Synchrotron Light

Brightness – many orders of magnitude brighter than conventional sources, enabling quick experiments on small samples.

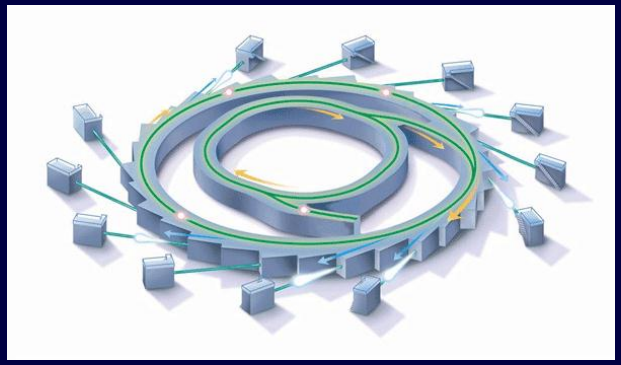


The BRIGHTNESS of Synchrotron Light

100 Watts / 1000000 mm^2 (1 m^2) =
0.0001 Watts / mm^2

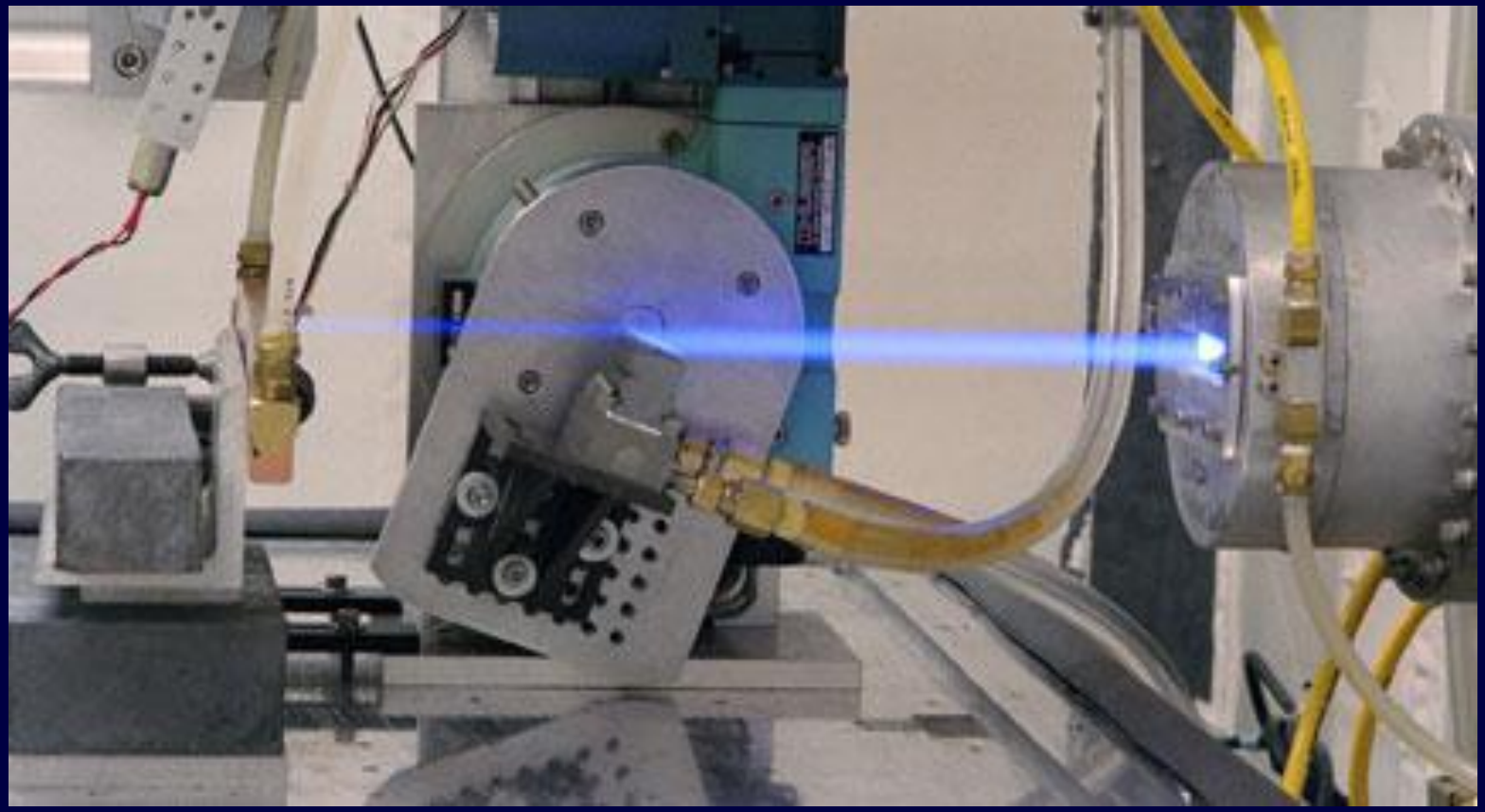


0.005 Watts / 1 mm^2 =
0.005 Watts / mm^2

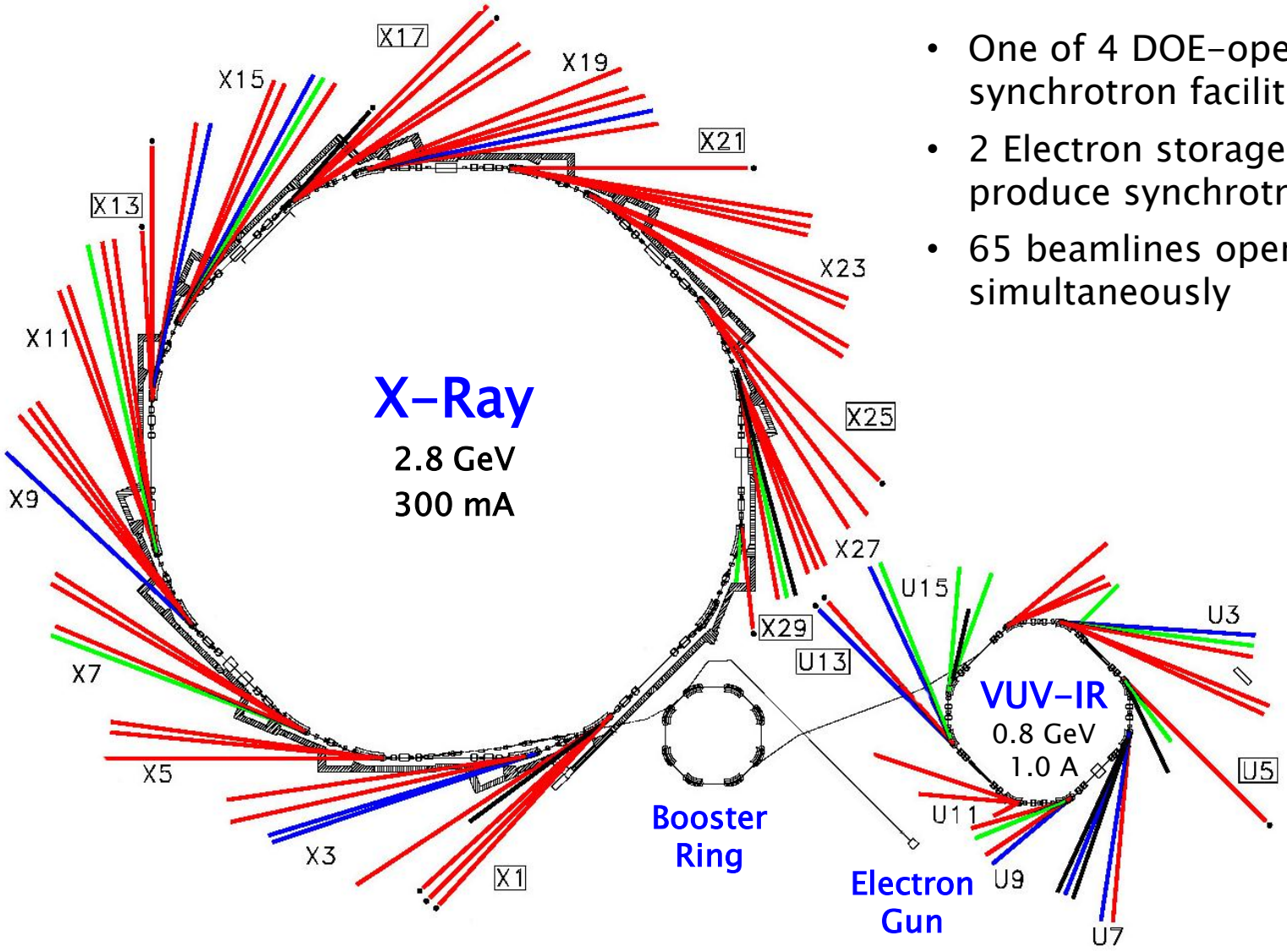


30 Watts / 0.01 mm^2 =
3000 Watts / mm^2

This is Synchrotron Light



How Do We Make Synchrotron Light?



- One of 4 DOE-operated synchrotron facilities
- 2 Electron storage rings that produce synchrotron light
- 65 beamlines operate simultaneously

Building a Synchrotron 101

1) Take evacuated beam pipe

ADD:

2) Bends (dipoles) to form e-beam trajectory (& as SR sources)

3) Quadrupole magnets to focus e-beam transversely

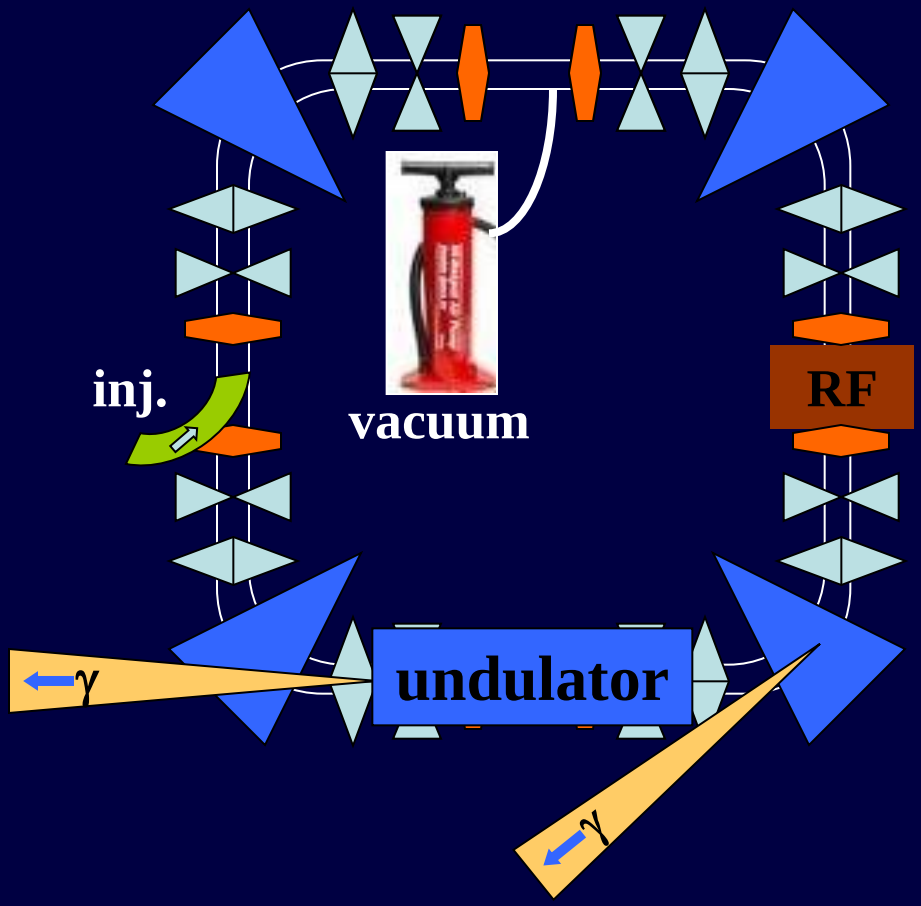
4) Sextupoles for achromatic focusing

5) RF to make up for energy loss; also provides longitudinal focusing (bunching)

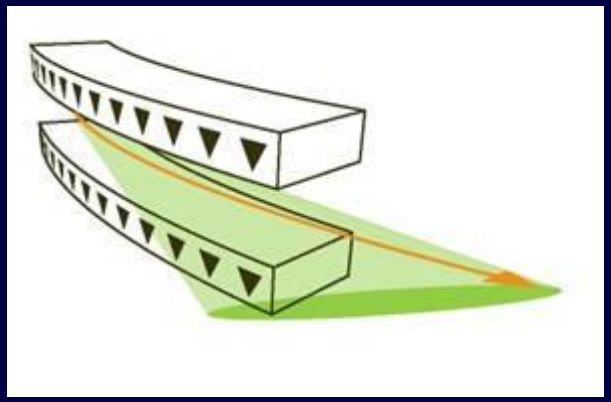
6) Injection system

7) IDs into avail. straight sections

8) Beamlines to deliver photons to the Users



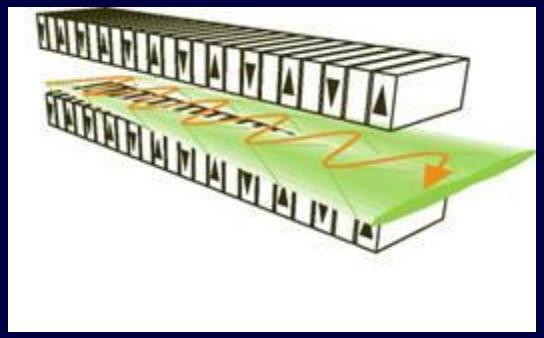
Types of Light-Generating Sources



Bending magnets:

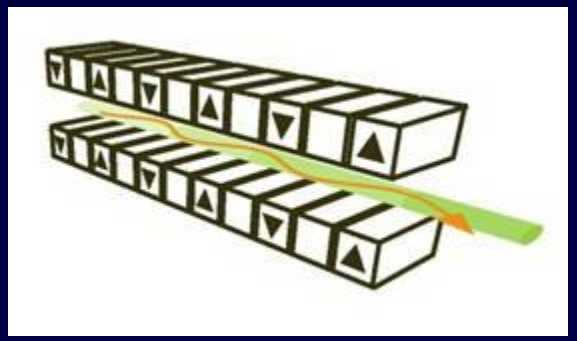
- Sweeping searchlight
- At each deflection of the electron path a beam of radiation is produced

Insertion devices – inserted into "straight sections" of the ring and produce higher intensity of light



Wiggler:

- Beams emitted at each pole reinforce each other and appear as a broad beam of incoherent light



Undulator

- Produces a very narrow beam of coherent light, amplified by up to 10,000x

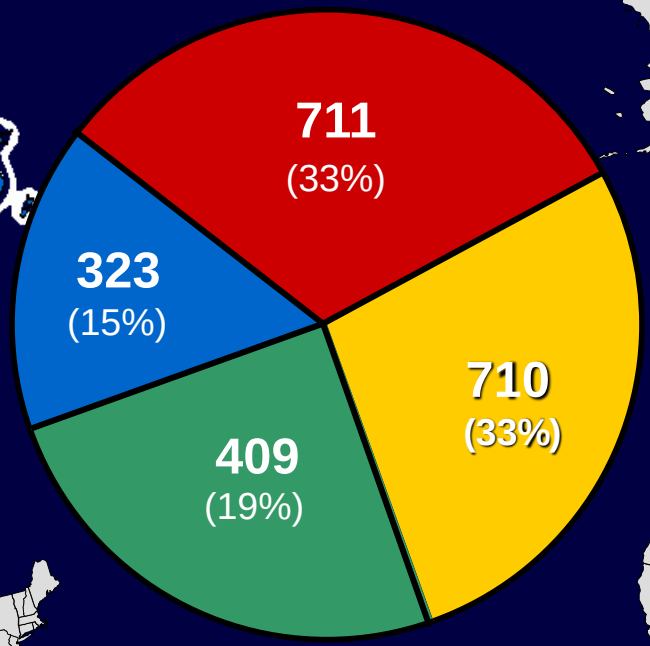
Outline

- The Facility
- The Users
- The Science
- The Future

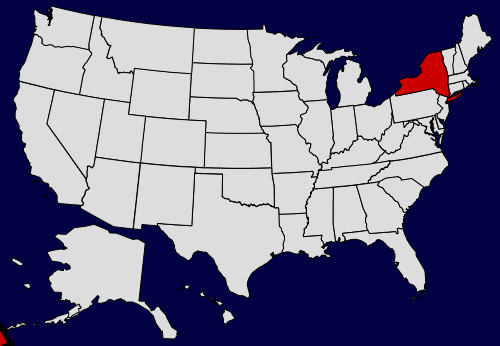
- Facility operates 24 hours/day, 7 days/week, ~10 months/year
- >2200 users per year (~1/3 are new users)
- Typical stay is 2-4 days (onsite housing)

NSLS User Distribution

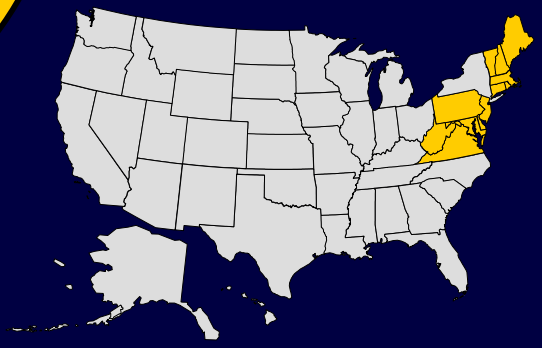
Foreign

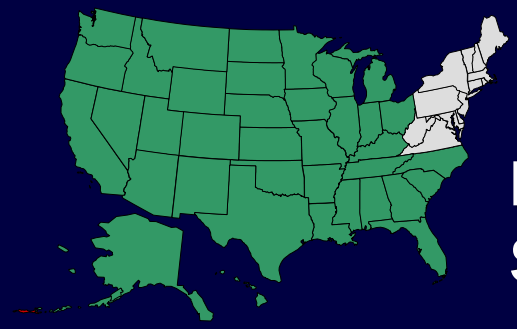


New York



Other Northeast States

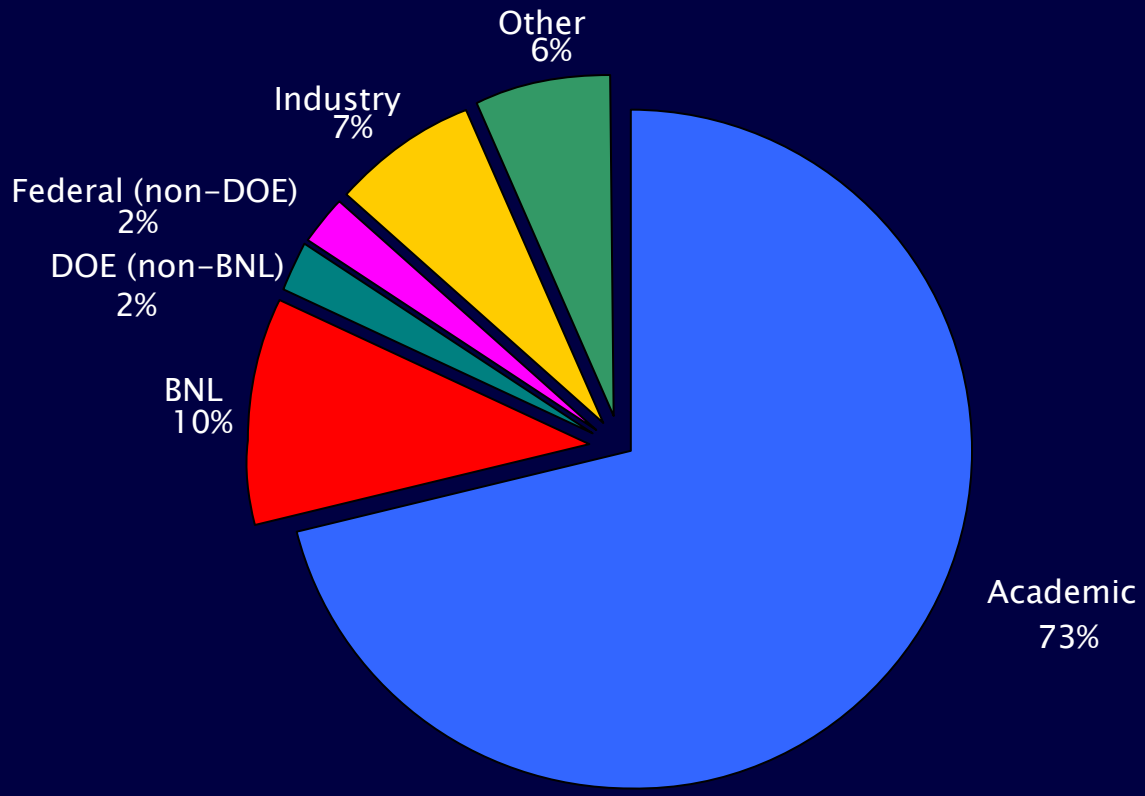




Non-Northeast States

FY 2010

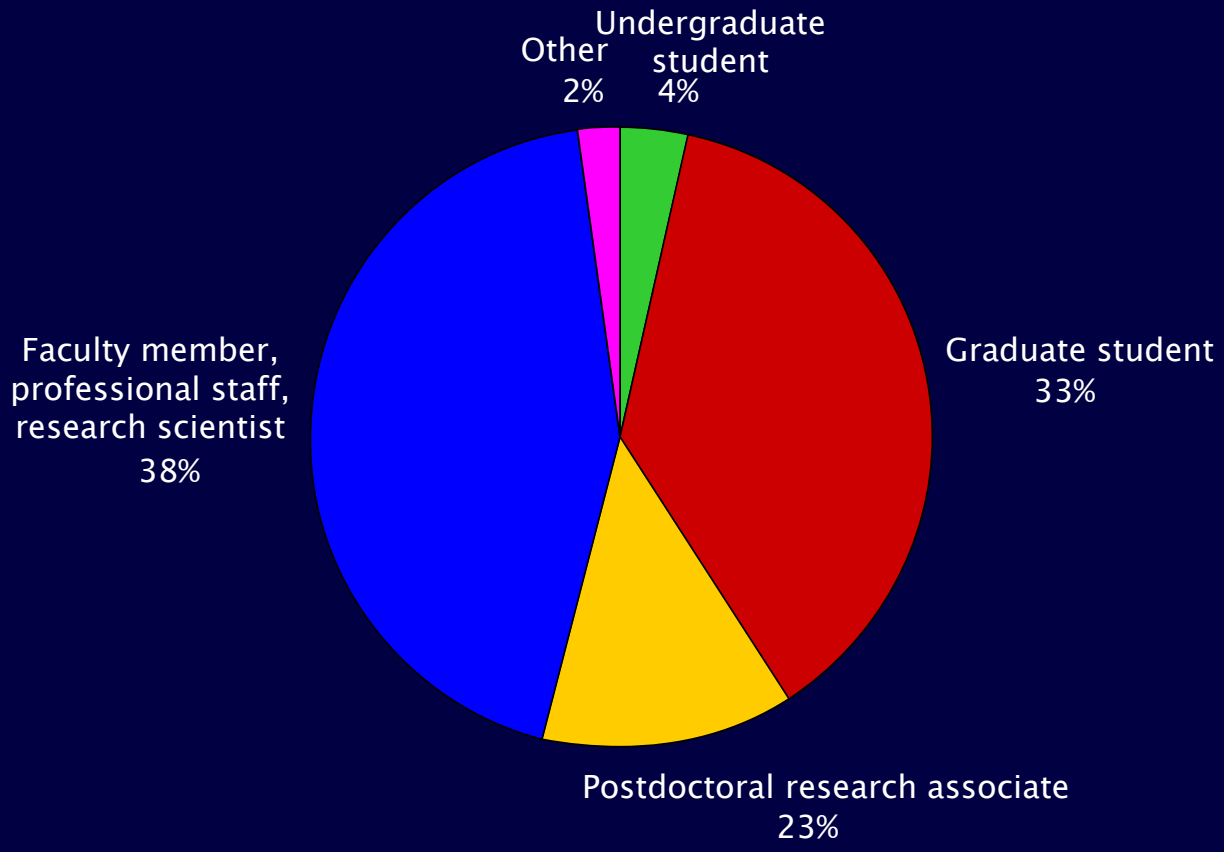
NSLS Users by Research Institution



- Large majority of users are from academia
- Industrial participation is small and diverse

FY 2010

NSLS Users by Employment Level



- A large number of students and postdocs work at NSLS

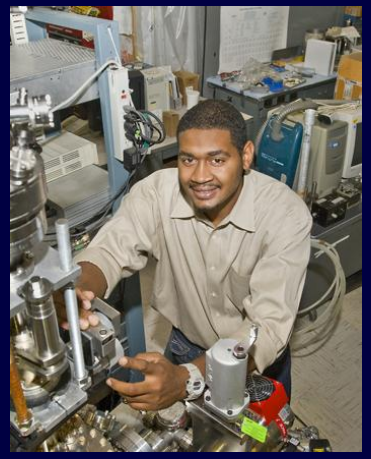
FY 2010

Student Research

Bishnu Panigrahi
college student
"heavy metal transport in plants"
Sayville, NY

Ashley Jones
college student
"Arsenic toxicity in the kidney"
Saginaw, MI

Megan Bourassa
PhD student
"metal homeostasis in ALS"
Phoenix, AZ



Jeff Ambrose
college student
"nitrogen fixation in soils"
New Orleans, LA

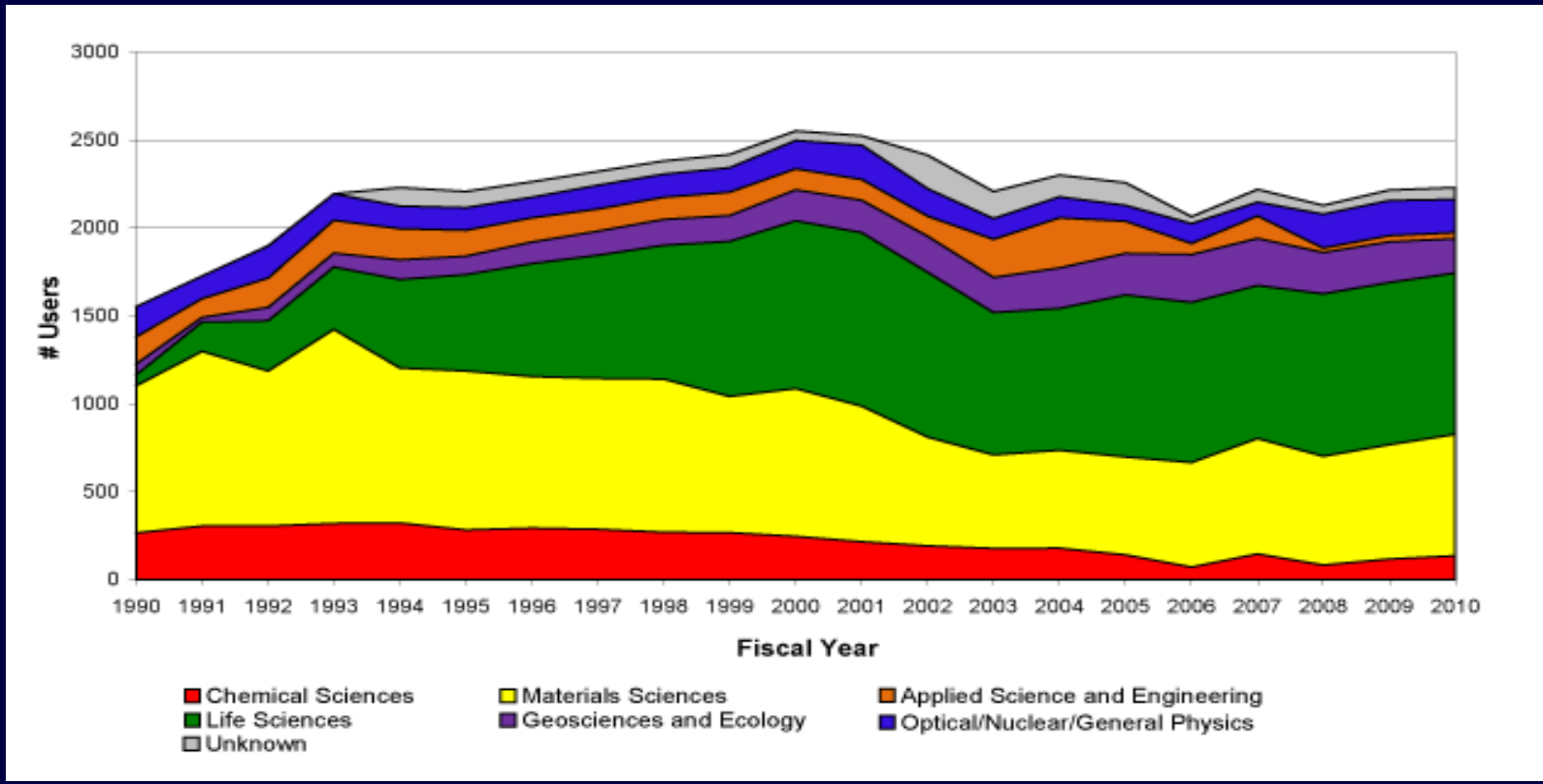
Matt Engel
PhD student
"protein structure in hepatitis C virus"
Stony Brook, NY

Andreana Leskovjan
PhD student
"metal uptake in Alzheimer's disease"
Tampa, FL

Alvin Acerbo
PhD student
"improving imaging resolution"
The Netherlands

Shirin Mortazavi
college student
"unique methods to crystallize proteins"
Bellport, NY

NSLS User Community



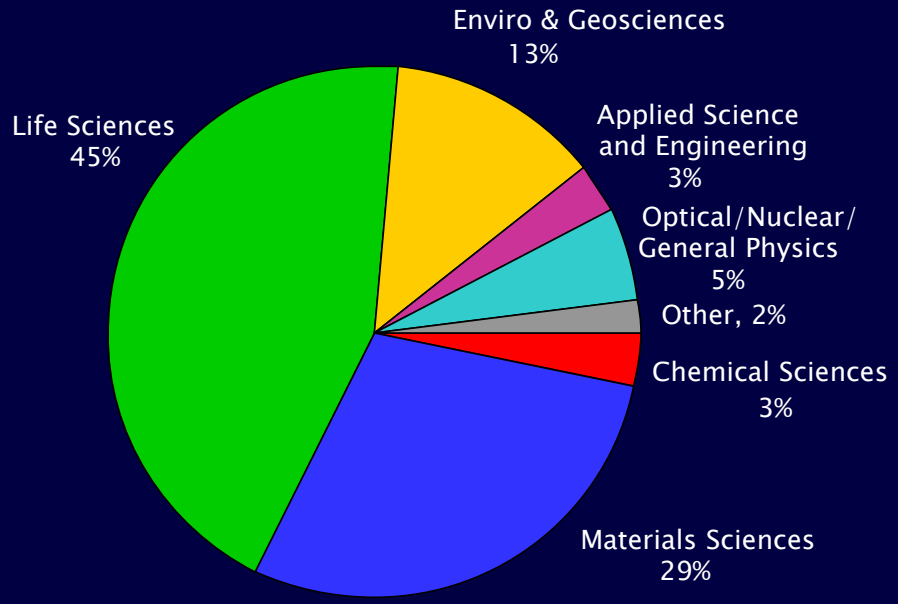
- >2100 scientists*
- >400 academic, industrial, government institutions

* users visiting the NSLS in FY 2010. Each year, the NSLS registers approximately 750 new users.

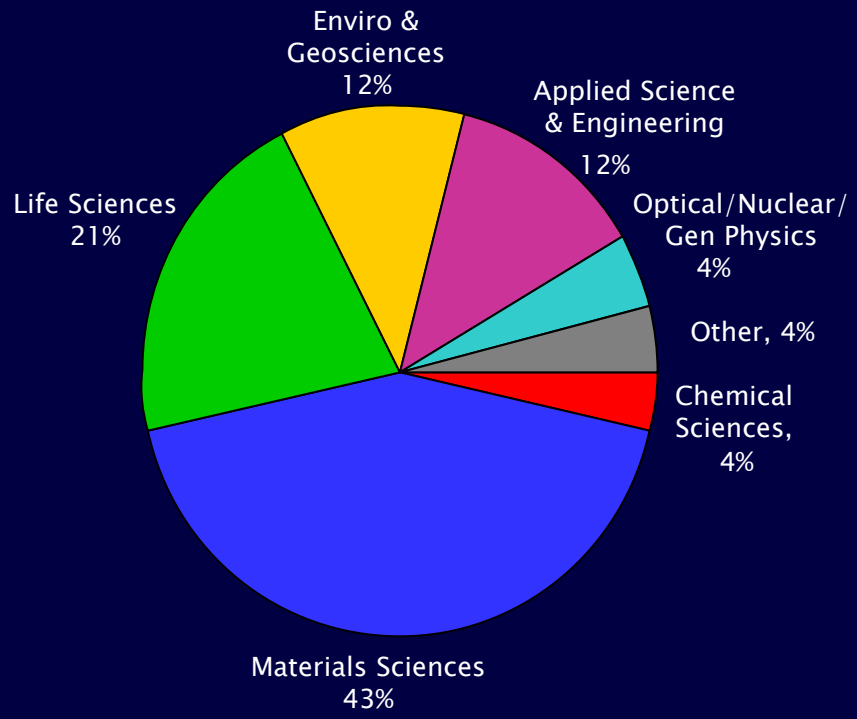
- 50% growth in last 12 years
- Strongest growth in life sciences
- Largest groups are materials and life sciences

Beamtime Used by Field of Research

Number of Users



Beamtime Used*



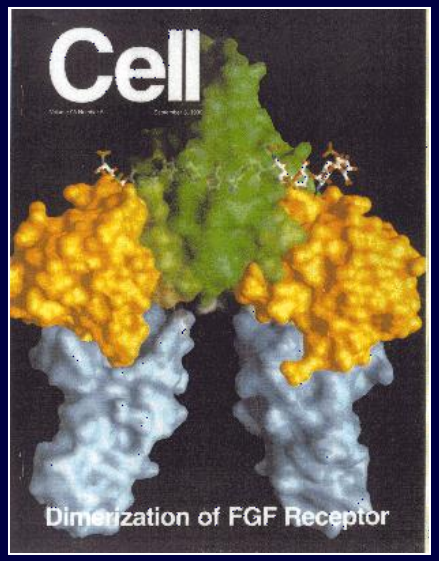
- More life science users, shorter beamtime, high-throughput
- Materials science experiments are more complicated, time-consuming

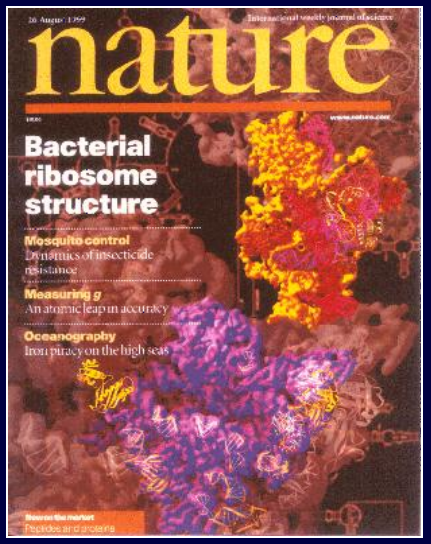
FY 2009

**Based on running times from Safety Approval Forms*

NSLS Publications

- almost 1000 publications per year
- > 200 publications in premier journals





How to Get Beamtime

- Scheduled in three 4-month cycles
- User access via 2 primary mechanisms:
  - General User Proposals: peer-reviewed proposal system
  - Participation Research Teams
- Some proprietary research is done (full cost-recovery rate)

Outline

- The Facility
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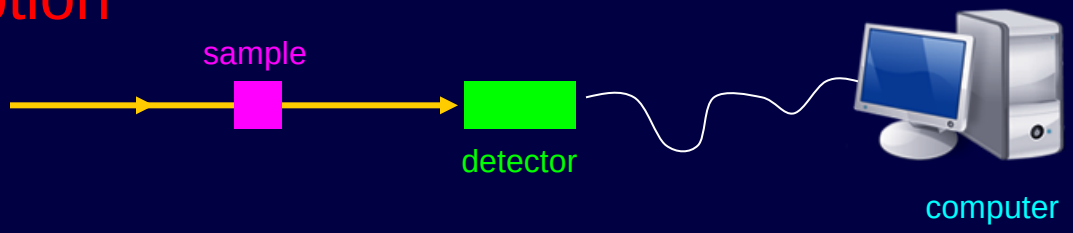
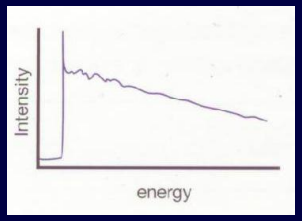
What do we do with Synchrotron Light?

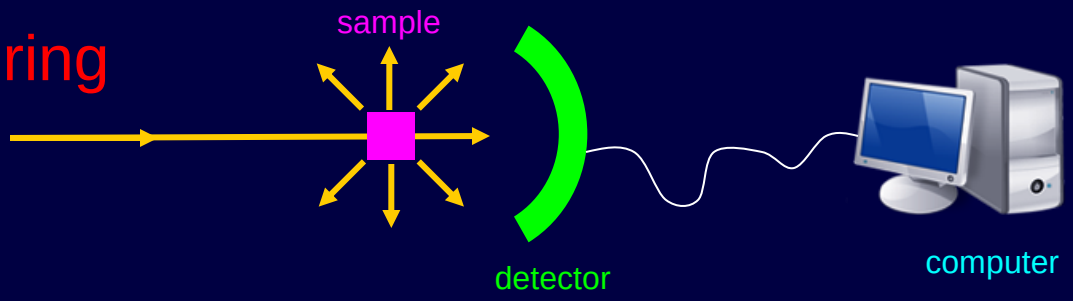
Absorption

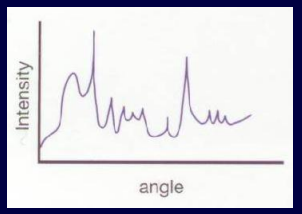




data

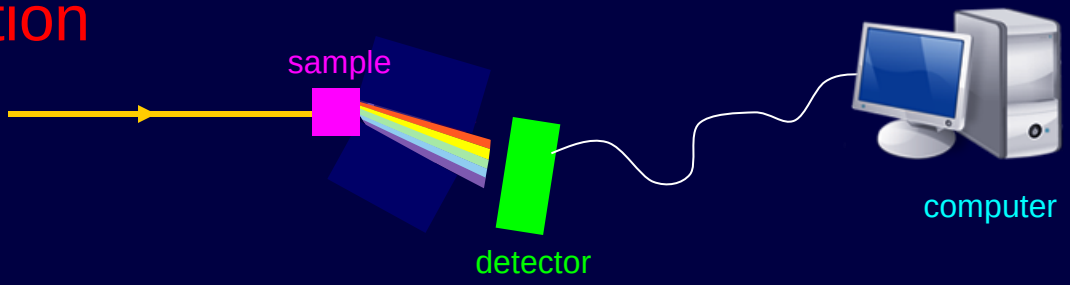
Scattering

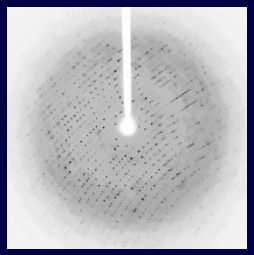




data

Diffraction





data

Major Synchrotron Techniques

SPECTROSCOPY

- Infrared spectroscopy
- Photoelectron spectroscopy
- X-ray absorption spectroscopy
- X-ray emission spectroscopy

DIFFRACTION/SCATTERING

- Protein crystallography
- Small molecule crystallography
- Powder diffraction
- Small-angle x-ray scattering
- X-ray microdiffraction
- High momentum resolution x-ray scattering

IMAGING

- Infrared microspectroscopy
- Soft X-ray scanning microscopy
- Hard X-ray microprobe
- X-ray microtomography
- Diffraction-enhance imaging

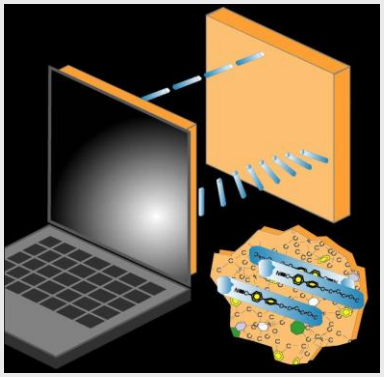
OTHER

- Micro-machining
- X-ray footprinting

Physics and Materials Science

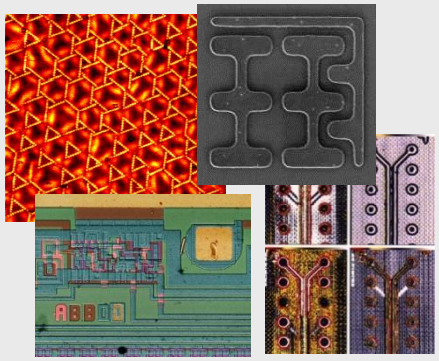
Data storage

Improved polymers



Liquid crystal displays

Nonstick coatings

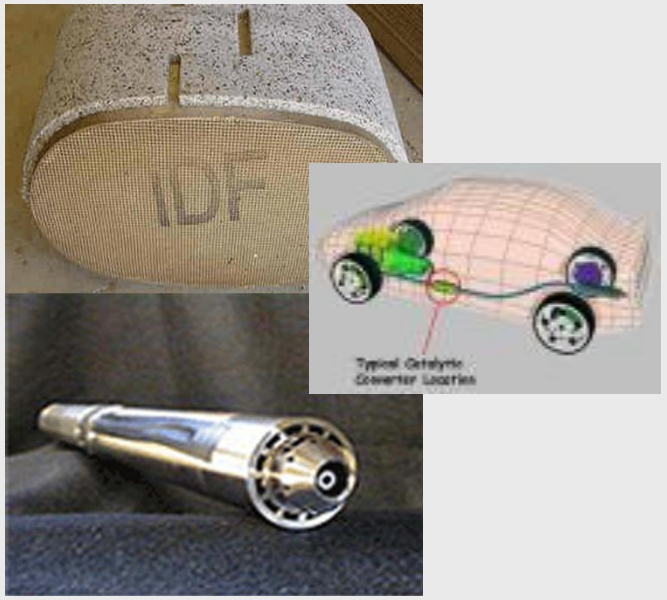


Nanomaterials

Chemistry

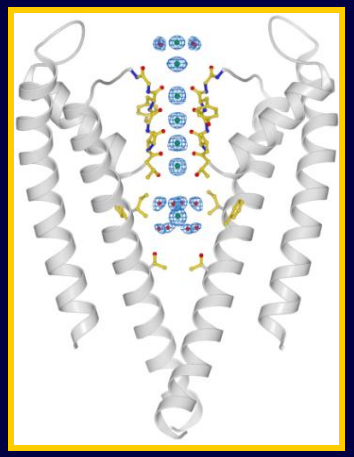
Corrosion

Rechargeable batteries



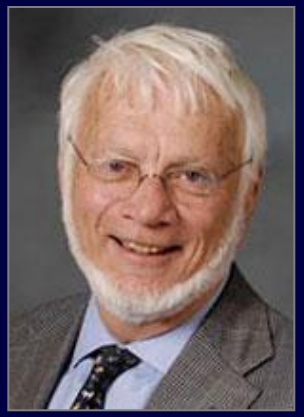
Catalytic converters

2003 and 2009 Nobel Prizes in Chemistry

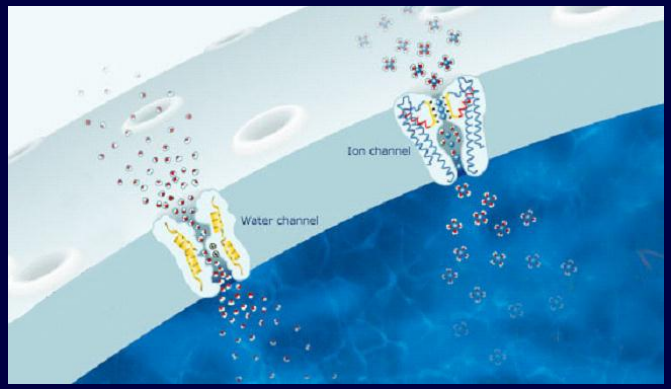


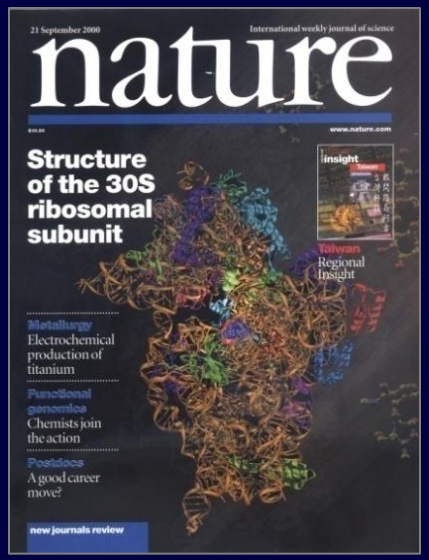
Rod MacKinnon

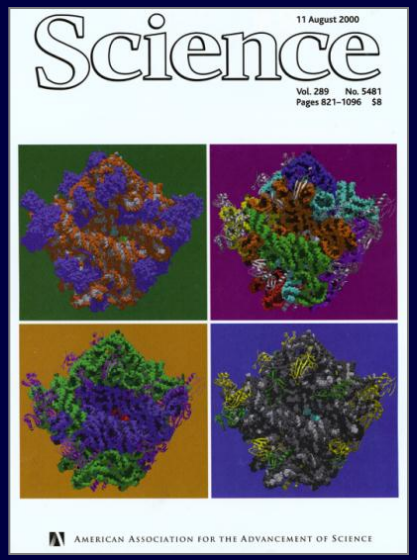
Venkatraman Ramakrishnan



Thomas Steitz





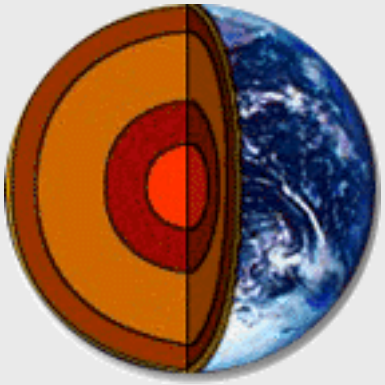


Geology and Environmental Science

Environmental cleanup

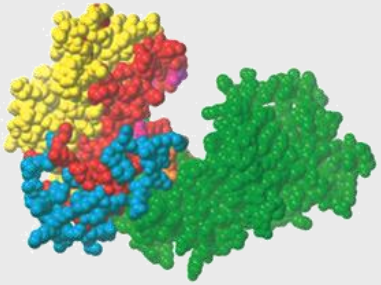
Mars meteorites

Space dust



Earth's core

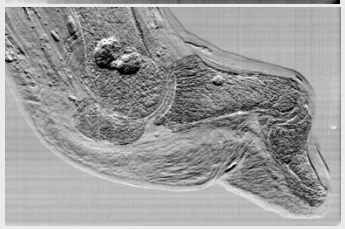
Biology and Medicine



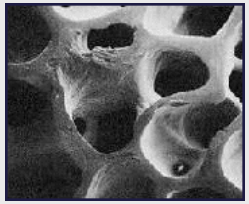
Anthrax

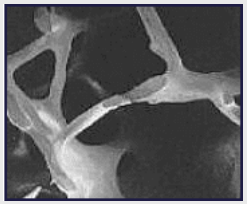
Malaria

Lyme's disease



Arthritis





Osteoporosis

HIV

Alzheimer's disease

Outline

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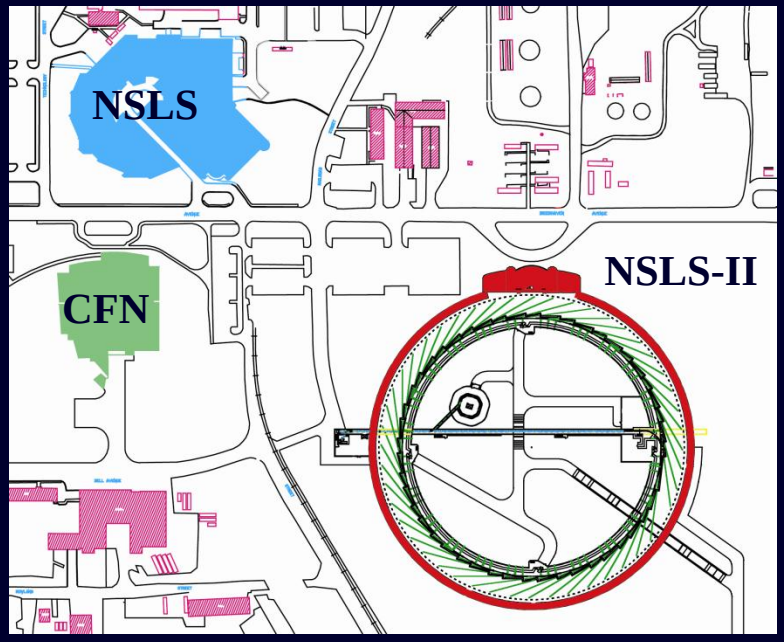
NSLS-II: Brighter Light for the Future

http://www.bnl.gov/nsls2/cam/

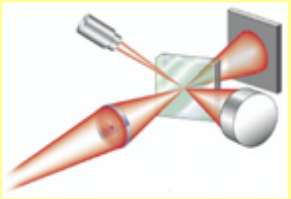
April 26, 2011



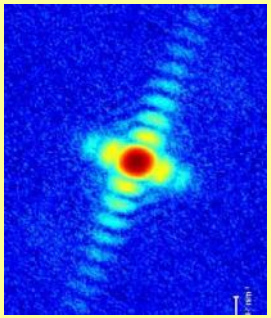
- new synchrotron under construction at Brookhaven Lab
- $912 M project to be completed in 2014
- x-rays ~10,000 times brighter than current NSLS
- will be the brightest synchrotron in the world

How is NSLS-II Different?

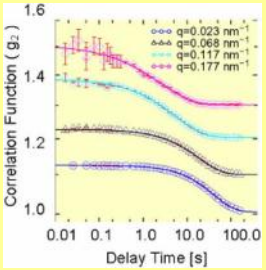
New



Imaging



Diffraction



Dynamics

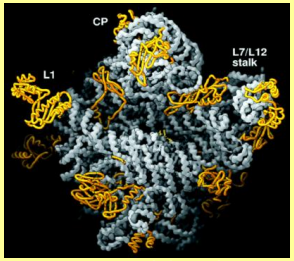
Highly optimized synchrotron delivering:

- extremely high brightness (10,000x)
- exceptional beam stability
- advanced instruments, optics, & detectors that capitalize on these special capabilities

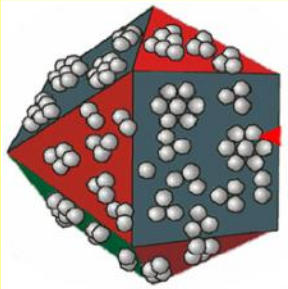
Together, these enable:

- ~ 1 nm spatial resolution
- ~ 0.1 meV energy resolution
- single atom sensitivity

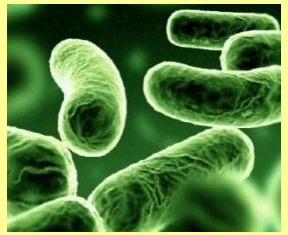
New Science



Structural biology



Nanocatalysis

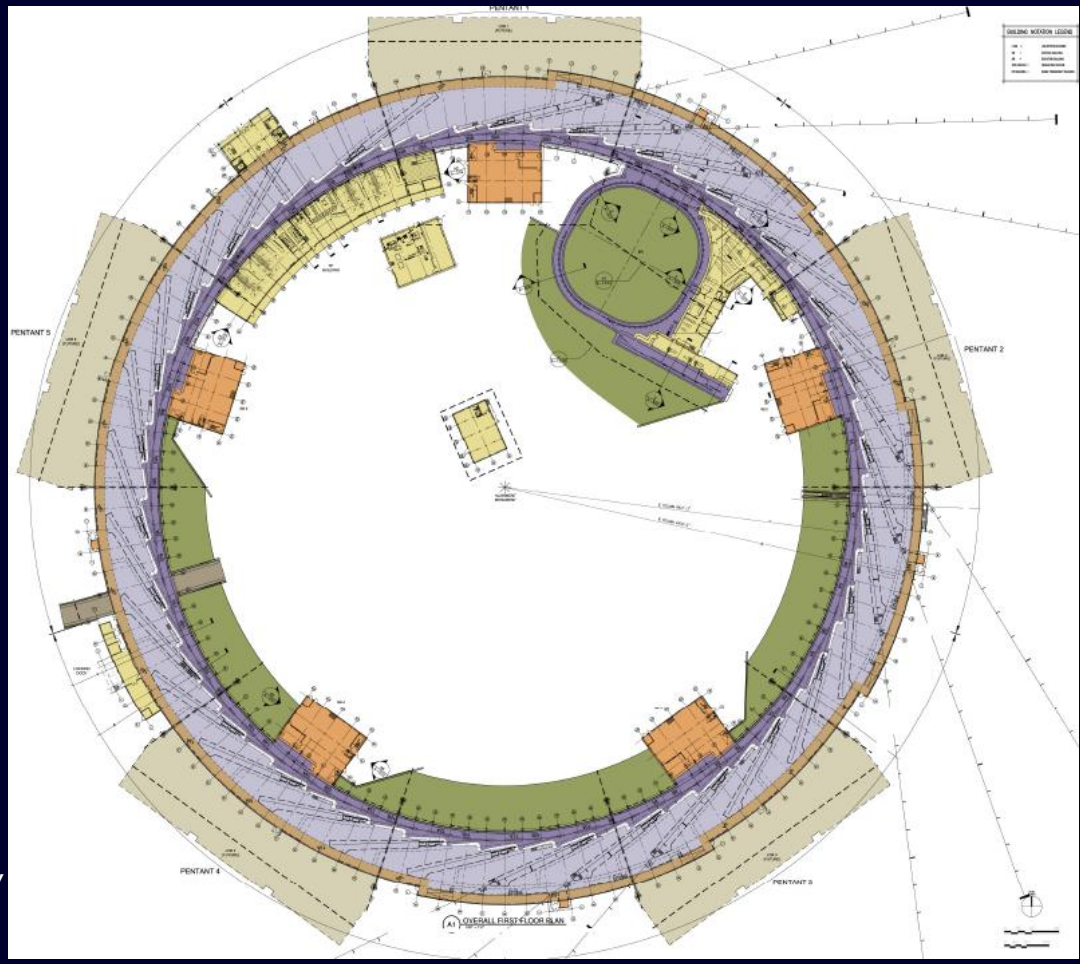


Carbon cycling

NSLS-II Design Features

Design Parameters

- 3 GeV, 500 mA, top-off injection
- Circumference 791.5 m
- 30 cell, Double Bend Achromat
  - 15 long, hi-β straights (9.3 m)
  - 15 short, lo-β straights (6.6 m)



Novel design features:

- Damping wigglers
- Soft bend magnets
- Three pole wigglers
- Large gap IR dipoles

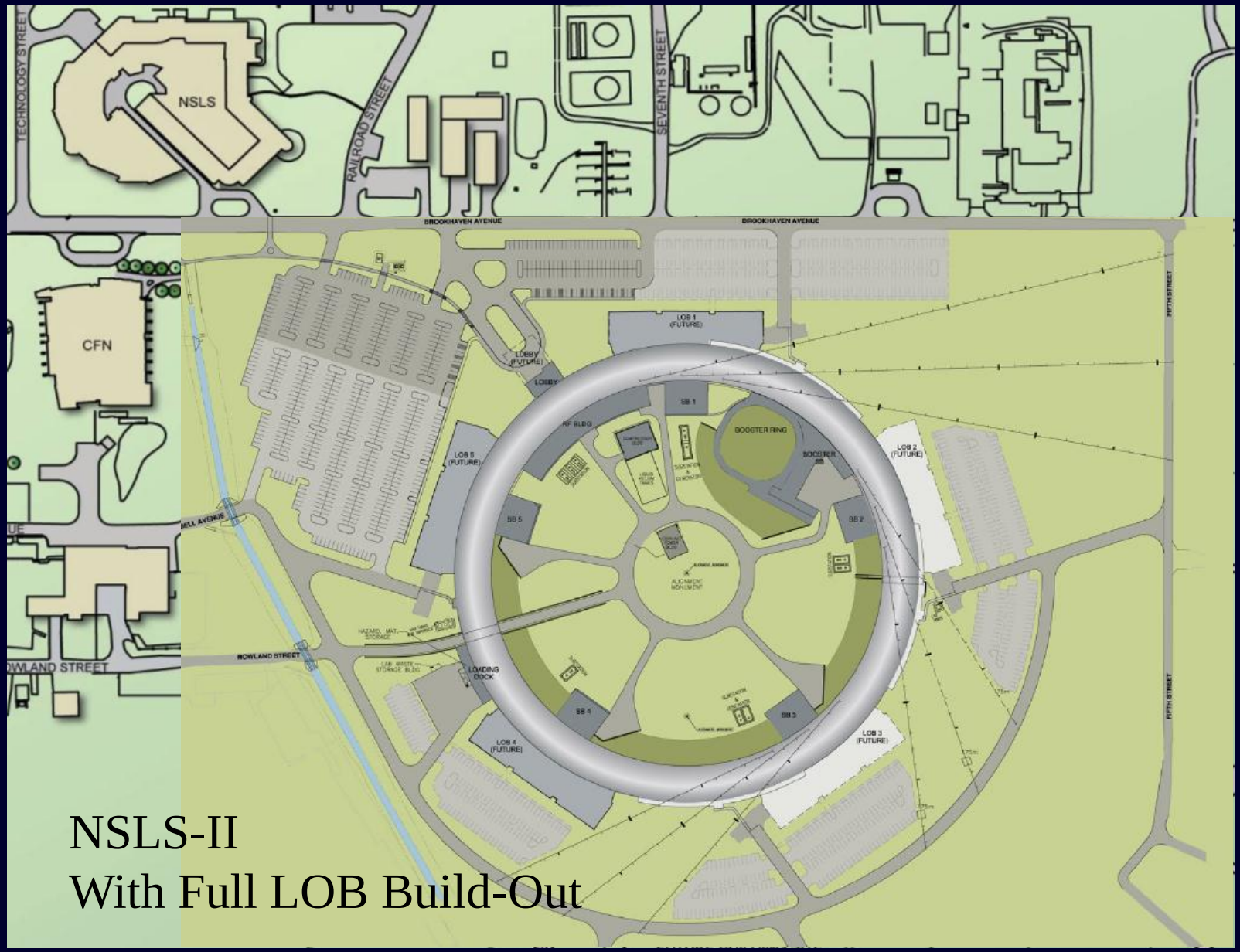
Ultra-low emittance

- Small beam size (e_x/e_y = 0.6 / 0.008 nm-rad)
- σ_x / σ_x = 28 μm / 2.6 μm, σ_x' / σ_y' = 19 μrad / 3.2 μrad
- Diffraction limited in vertical at 10 keV

Pulse Length (rms) ~ 15 psec

Total Project Cost = $912M

NSLS-II Site Plan



NSLS-II
With Full LOB Build-Out

Lab-Office Building (LOB) Floor Plan

- SCIENTISTS
- SCI. ASSOCIATES
- POSTDOCS
- STUDENTS
- USERS
- TECHS
- LABS
- MACHINE SHOP
- FACILITY COORD
- CONFERENCE
- KITCHEN
- ADMIN
- MAIL & P/C

33,600 Gross Square Feet

- 120 Offices
- 10 labs
- Machine shop
- Conference Rooms
- Interaction Areas
- Loading/storage area

Current project scope:

- 2 built-out LOBs
- 1 shell (maybe 2-3)

NSLS-II Beamlines

- 19 straight sections for undulators
- 8 straight sections for damping wigglers
- 27 BM ports for IR, UV and Soft X-rays
- 4 Large Gap BM ports for far-IR

At least 58 beamlines
More beamlines by canting multiple IDs per straight
Multiple end-stations/beamline are also possible

For comparison, NSLS has 60 operating beamlines